#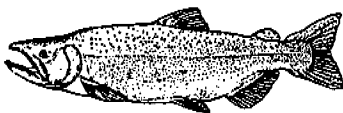 IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA

Annual Progress Report
Fiscal Year 1997

U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3310 El Camino, Suite 130
Sacramento, CA 95821

Prepared by staff of
The Instream Flow Assessments Branch

PREFACE

The following is the third annual progress report prepared as part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (FWS) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this program and the habitat resources of Central Valley rivers are welcomed. Written comments or information can be submitted to:

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Jeff Thomas, Chief
Instream Flow Assessments Branch
U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3310 El Camino, Suite 130
Sacramento, CA 95821

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late fall, winter, and spring), steelhead trout, and white and green sturgeon. In December 1994, the USFWS, Ecological Services, Instream Flow Assessments Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. Subsequently, as discussed in our first annual report, the Sacramento, lower American and Merced Rivers were selected for study. The studies on these rivers have been and will continue to be closely coordinated with study efforts being conducted by CDFG.

The Sacramento River study is a five-year effort to be concluded in September, 1999. Specific goals of the study are to determine the relationship between streamflow and physical habitat availability for all life stages of chinook salmon (fall-, late fall-, winter-runs) and to identify flows at which redd dewatering and juvenile stranding conditions occur. The instream flow requirements for white and green sturgeon may also be studied; however, the inclusion of these species depends upon the availability of resources and sufficient data to enable identification of the habitats used by them. The study components include: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The FY97 Scope of Work (SOW) identified study tasks to be undertaken. These included: field reconnaissance (study component 3); study site selection, transect placement, and hydraulic and structural data collection (study components 5 and 6); study site selection and field data collection for development of a two-dimensional instream flow model; and continuing the development of HSC (study component 4).

The lower American River study was a one-year effort which culminated in a March 27, 1996 report detailing the methods and results of this effort. This report was submitted to CDFG for enclosure in their final report on the lower American River. Subsequently, questions arose as to which of the chinook salmon spawning HSC criteria used in the March 27, 1996 report would be transferable to the Lower American River. As a result, additional field work was conducted in FY97, culminating in a supplemental report submitted to CDFG on February 11, 1997.

The Merced River study was a 1.5 year effort to be concluded by June 30, 1997 as indicated in the FY97 SOW. The purpose of this study was to produce a habitat model predicting physical habitat availability for spawning fall-run chinook salmon. This information was to supplement data which have been collected by CDFG for several years to produce comprehensive instream

flow recommendations. A report detailing the methods and results of this effort was submitted to CDFG on March 19, 1997 for enclosure in their final report on the Merced River. Study components included: 1) field reconnaissance and selection of study sites; 2) placement of transects in selected study sites; 3) hydraulic and structural data collection; 4) construction and calibration of reliable hydraulic simulation models; 5) construction of habitat models to predict spawning habitat availability over a range of river discharges; and 6) preparation and submittal of a report detailing study procedures and model results. A copy of the report was also provided to staff of the CVPIA Anadromous Fish Restoration Program.

The following sections summarize project activities between October, 1996 and September, 1997.

SACRAMENTO RIVER

Field Reconnaissance and Study Site Selection

Field reconnaissance in FY97 investigated potential study sites where habitat modelling will be undertaken for chinook salmon and may be undertaken for white sturgeon spawning. The following two sections describe the methods employed and the results of FY97 reconnaissance efforts for these two species.

Chinook salmon spawning habitat

During FY97, we followed up on the ranking of mesohabitat units in each of the stream segments[1] in our FY96 annual report (Table 1). The aerial redd data from which these rankings were derived is found in Appendix A. In March and April, 1997 we conducted a reconnaissance of the sites in Segments four through six to determine their viability as study sites. Each site was evaluated based on morphological and channel characteristics which facilitate the development of reliable hydraulic models. Also noted were riverbank and floodplain characteristics (e.g. steep, heavily vegetated berms or gradually sloping cobble benches) which might affect our ability to collect the necessary data to build these models. For the sites selected for modeling, the landowners along both riverbanks were identified and temporary entry permits were sent, accompanied by a cover letter, to acquire permission for entry onto their property during the course of the study.

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[1] As discussed in the FY95 annual report, we have divided the Sacramento River study area into six stream segments, based on hydrology and other factors: Colusa to Butte City (Segment 1); Deer Creek to Red Bluff Diversion Dam (Segment 2); above Lake Red Bluff to Battle Creek (Segment 3); Battle Creek to Cow Creek (Segment 4); Cow Creek to ACID (Segment 5); and ACID to Keswick (Segment 6). Segment 1 addresses green and white sturgeon, while the other segments address chinook salmon.

Table 1
Top-ranked Mesohabitat Units for Chinook Salmon Spawning
Based on Aerial Redd Survey Data

Stream Segment	River Mile	Location	Races[2]
6	298.7-298.8	Lower Lake Redding Site	LF
6	299-299.3	Upper Lake Redding Site	LF
6	300.6	Salt Creek Site	LF
6	299.9	Island Site	LF
5	296.3-296.4	299 Bridge Riffle Site	F, LF, W
5	287.6-287.7	Knighton Riffle Site	F
5	297.2	Turtle Bay Side Channel Site	F, LF
5	297.7-298	Posse Grounds Site	F, LF, W
5	282.7-282.8	Above Hawes Hole Site	F, LF
5	298.4	Bridge Riffle Site	F, LF, W
5	291.8	Tobiasson Riffle Site	W, (F, LF)
5	296.6-296.8	Palisades Site	W
5	293.2	Canyon Creek Site	W
4	279.2	Powerline Riffle Site	F, LF, W
4	277.5	Bear Creek Site	F
4	276.1	Balls Ferry Riffle Site	F, LF
4	271.5-271.7	Price Riffle Site	F, LF, W
4	273.4-273	Cottonwood Riffle Site	F, LF, W
4	279.7	Below Cow Creek Site	LF
3	270.2-270	Mud Ball Riffle Site	F
3	269.5-269.2	Laurence Riffle Site	F
3	268.7-268.4	Freitas Riffle Site	F
3	266.3-266.2	Jellys Ferry Riffle Site	F
3	257.9-258	Upper Bend Riffle Site	F
2	240.3-240.7	Osborne Riffle Site	F
2	239.2-239.5	Blackberry Riffle Site	F
2	222.9-223.2	Five Fingers Riffle Site	F
2	241.5-241.8	Pipeline Riffle Site	F
2	222.5	unnamed	F

[2] F = fall-run, LF = late fall-run, W = winter-run. Races in parentheses were not ranked among the highest for that stream segment, but are included because they used the mesohabitat unit relatively heavily and the mesohabitat unit was ranked high for another race.

After reviewing the field reconnaissance notes and considering time and manpower constraints, eight study sites were selected for modelling: 1) Salt Creek; 2) Upper Lake Redding; 3) Lower Lake Redding; 4) Bridge Riffle; 5) Posse Grounds; 6) Above Hawes Hole; 7) Powerline Riffle; and 8) Price Riffle. The first three of these are in Segment 6 and are used by spawning late fall-run salmon. Sites four and five are located in Segment 5 and are used by all three chinook races; site six is also in Segment 5 and used by fall- and late-fall run salmon. Sites seven and eight are used for spawning by all three races and are located in Segment 4. The river mile location of each of these sites is found in Table 1. Two additional study sites, Canyon Creek (used by winter-run) in Segment 5 and Bear Creek (used by fall-run salmon) in Segment 4, may eventually be included pending time availability.

In Segment 6 the Island Site was bypassed due to its low ranking and the inclusion of the other three sites in the segment. In Segment 5, the Turtle Bay Side Channel and Highway 299 Bridge Riffle sites were eliminated because changes in the channel morphology had occurred in two successive years and it was feared that any data collected at these sites would not remain valid; the Palisades and Tobiasson Riffle sites were not included due to hydraulic complexities (i.e., transverse and reverse flow patterns) which would be impossible to model effectively with the single dimension hydraulic models within PHABSIM[3]; Knighton Riffle was not selected because of potentially insurmountable logistical problems with surveying the site to obtain bed and water surface elevations. In Segment 4, the Balls Ferry Site was eliminated due to the presence of heavily vegetated levees on both riverbanks which exceeded heights of 20-25 feet; the sites below Cow Creek and at Cottonwood Riffle were not included due to their low ranking and because two more heavily used spawning areas had already been selected in the segment.

White sturgeon spawning habitat

In February, 1997 we reconnoitered white sturgeon spawning areas in Reach 1 (Colusa to Butte City). In general, we were looking for areas with depths greater than 6 feet, velocities greater than 4 ft/s and substrate of gravel or larger. Within this area, there are four sites with known white sturgeon spawning, based on eggs collected by CDFG: Moon Bend (RM 138.8), Cruise and Tarry (RM 145.5), Below Moulton Weir (RM 156.2) and Log Jam (RM 156.7). We took depth and velocity measurements at four likely sites (RM 166.5, 165, 163 and 157) and found that these sites had adequate velocities and depths for sturgeon spawning, but were unable to determine the substrate size. With adequate water clarity, we would be able to use the underwater video equipment described below to select sites with useable substrate. However, the lower Sacramento River is characterized by generally turbid conditions and this option remains

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[3] PHABSIM is the Physical Habitat Simulation component of the IFIM. It is the collection of hydraulic and habitat models which are used to predict the relationship between physical habitat availability and streamflow over a range of river discharges.

questionable. At this time it appears that modelling spawning habitat for this species would be primarily a shot in the dark and that our time and effort would be better spent concentrating on the anadromous salmonids.

Transect Placement (study site setup)

A total of 34 transects have been placed in the established study sites. At each site, transects were located to cross the areas most heavily used by spawning chinook salmon (as identified by Kurt Brown, Red Bluff FWS and on CDFG aerial photographs). Transect pins (headpins and tailpins) were marked on each river bank above the 15,000 cfs water surface level using rebar driven into the ground and/or lag bolts placed in tree trunks. Survey flagging was used to mark the locations of each pin. The study sites, reach number, and number of transects placed at each site are shown in Table 2.

Table 2
Sacramento River Chinook Spawning Sites

Site Name	Reach Number	Number of Transects
Salt Creek	6	1
Upper Lake Redding	6	2
Lower Lake Redding	6	1
Bridge Riffle	5	3
Posse Grounds	5	10
Above Hawes Hole	5	6
Powerline Riffle	4	6
Price Riffle	4	5

Hydraulic and Structural Data Collection

Benchmarks were established at each site to serve as the reference elevation to which all elevations (streambed and water surface) will be tied. The data collected on each transect include: 1) water surface elevations (WSELs), measured to the nearest .01 foot at three significantly different stream discharges using standard surveying techniques (differential levelling); 2) wetted streambed elevations determined by subtracting the measured depth from

the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate classification at these same locations and also where dry ground elevations were surveyed. Hydraulic and structural data collection began in May 1997.

Water surface elevations have been measured at all sites except Posse Grounds transects one through eight at a high flow (approximately 15,000 cfs) and at all sites except Price Riffle at a mid-range flow (approximately 10,000 cfs). High flow depth and velocity measurements have been collected at all sites except Above Hawes Hole and Posse Grounds (transects one through eight). Depth and velocity measurements in portions of the transects with depths greater than three feet were made with the Broad-Band Acoustic Doppler Current Profiler (ADCP), while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney^R model 2000 velocity meter. We plan to collect depths and velocities at a high flow for Posse Grounds transects one through eight, but are waiting until turbidity decreases enough to enable safe boat operations on those transects. As a result of a lateral bar at the Above Hawes Hole site, we will collect depth and velocity data at a mid-range flow, rather than a high flow.

Habitat Suitability Criteria (HSC) Development

Spawning

Methods

Depth, velocity and substrate data were collected on fall-run chinook salmon redds on October 28 and November 25, 1996. Data were collected in shallow areas on October 28 by wading, while data were collected in deeper areas on November 25 using the ADCP. All data were entered into a spreadsheet for eventual analysis and development of Suitability Indices (HSC).

All of the active redds (those not covered with periphyton growth) within a given mesohabitat unit were measured. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about two to four feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were always collected within six feet of the pit of the redd. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. Substrate was visually assessed for the dominant particle size and particle size range (e.g., dominant size of 2" and range of 1-2"). Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. Sacramento River flows (releases from Keswick Reservoir) averaged 5,350 cfs ± 7.5% from October 11 through November 25. Since few fall-run salmon had started constructing redds prior to October

11, these steady flow conditions ensured that the measured depths and velocities were likely the same as those present at the time of redd construction. In addition, many of the measured redds still had adult salmon holding nearby, providing further indication of recent redd construction. Fall-run spawning HSC data collection will continue during the 1997 and 1998 fall-run spawning seasons.

Due to extremely high turbidity from early January through the present, it was impossible to collect any late fall-run HSC data. This chinook race spawns during the peak of the winter/early spring storm season (January through mid-April) when river flows are often very high and erratic. As a result, it appears increasingly unlikely that late fall-run spawning criteria can be developed in this study. The unusually high turbidity during the winter-run spawning season (May through early July) also precluded the collection of spawning HSC for this race. The development of winter-run criteria will require a large effort in FY98 and FY99. The effort to collect spawning HSC data for the late fall-run and winter-run will continue for the 1998 and 1999 spawning seasons, river conditions permitting.

Results

Data were collected on a total of 73 fall-run chinook salmon redds. Three mesohabitat units were sampled (one Flat Water (FW) Glide, one Side-Channel (SC) Riffle, and one FW Riffle). As mentioned above, no data were collected for the late fall-run or winter-run.

Deep water techniques

Experience to date has shown that some chinook salmon in the Sacramento River spawn in water too deep to visually search for redds using conventional techniques (e.g. wading or from the bow of a boat). Without the inclusion of measurement data from these deep redds, should they be of significant number, spawning depth criteria would be inherently biased towards shallow water. Consequently, we have successfully acquired, assembled and field tested underwater video equipment for locating redds (and identifying substrate composition along transects) in deep water. We were not be able to use the equipment in FY97 for these purposes due to the turbidity problem discussed above but intend to use it this fall to locate fall-run redds in deeper water. The equipment consists of two waterproof remote cameras mounted on an aluminum frame with two 30-lb. bombs. The frame is attached to a cable/winch assembly, while a separate cable from the remote cameras is connected to three TV monitors on the boat. One of the monitors is used by the boat operator to hold position on a redd, while the other two monitors are used by the winch operator to locate redds and determine the substrate size. Since the video equipment is mounted on the jetboat we use to deploy the ADCP, we will be able to locate and measure redds with a three-person crew and cover large areas of the river.

Rearing

Considering that the observational method used in collecting rearing data for salmonid fry and juveniles is direct underwater (snorkeling), we were unable to collect any data this fiscal year (once again due to reduced water clarity). The methods described in the FY96 Annual Report will be employed again in fiscal years 1998 and 1999 to collect additional rearing HSC data. In response to a request from the USGS, Midcontinent Ecological Sciences Center (MESC) for chinook salmon rearing criteria to be considered for use on the Klamath River, we used the data collected in FY96 to derive preliminary HSC for chinook salmon rearing in the Sacramento River. These criteria and the methods used to develop them are contained in the report included in Appendix B.

LOWER AMERICAN RIVER

In response to questions which arose as to which of the HSC for chinook salmon spawning used in our March 27, 1996 final report would be transferable to the lower American River, we began to collect depth, velocity and substrate data to perform transferability tests (Thomas and Bovee, 1993). The transferability test procedure requires measurements of at least 55 occupied and 200 unoccupied cells. Data relative to these variables were collected from 218 fall-run chinook salmon redds (i.e., occupied cells) on November 6 and 7, 1996 at five of our lower American River study sites. In addition, depth, velocity, and substrate data were collected from 128 locations without redds (i.e., unoccupied cells) on December 3, 1996 at three of our lower American River study sites. Unfortunately, the first significant winter rains intervened, river flows increased, and we were unable to collect any more unoccupied data precluding the possibility of running the tests. Instead, we used the data from the redds to develop site-specific HSC for fall-run chinook salmon spawning. These criteria were used with the results of the hydraulic modelling conducted in FY96 to develop revised habitat models predicting habitat availability (weighted useable area) for fall-run chinook salmon spawning at flows ranging from 1000 to 6000 cfs .

This effort was detailed in a supplemental report submitted to both CDFG and CVPIA Anadromous Fish Restoration Program staff on February 11, 1997. The report is attached as Appendix C.

As a result of the 115,000 cfs flood releases made into the lower American River in January of this year, considerable morphological changes have occurred in many areas of the river including some of our study sites. As a result, CDFG has inquired into the possibility that we collect additional hydraulic and structural data, and develop new spawning habitat models for fall-run chinook salmon on the lower American River. This will only be possible should the Project schedule be extended past the current completion date of September 30, 1999.

MERCED RIVER

Hydraulic and structural data collection on established transects was completed in October, 1996. These data were used to construct and calibrate hydraulic models at each study site. Site-specific HSC for fall-run chinook salmon were developed from measurements of 186 fall-run chinook salmon redds made October 12 through 14, 1996. These criteria, along with HSC developed for the Stanislaus and Tuolumne Rivers, were used with the results of the hydraulic modeling to produce habitat models predicting habitat availability (weighted useable area) for fall-run chinook salmon spawning.

The final report for the study presents weighted useable area, by transect, for the 23 transects modelled in seven study sites at flows ranging from 200 to 700 cfs using eight sets of fall-run chinook salmon spawning HSC. The final report for the study contains a details of the field techniques employed, methods and procedures followed, and the results. It was submitted to both CDFG and CVPIA Anadromous Fish Restoration Program staff on March 19, 1997.

As was the case on the lower American River, extremely high flows in January, 1997 resulted in major morphological changes to the Merced River channel. All of our study sites except that placed directly below the Crocker-Huffman Dam (Hatchery Site) were significantly affected. The most dramatic changes were observed in the two sites furthest downstream (Sodbuster and Bullfrog Riffles) which were left dry when the river changed course after a levee separating the channel from abandoned gravel pits washed out. As a result, the results of our study no longer reflect the current conditions in the Merced River. It is likely that some of our study sites will no longer be used heavily for spawning. Furthermore, in sites which might still be used, the areas which were documented as having the highest concentrations of redds in years past (and across which transects were placed) cannot be expected to display similar utility in the future. The Merced River will require a completely new modeling effort which will only be possible if the Project schedule is extended past the current completion date of September 30, 1999.

Two-dimensional habitat modeling

On the Sacramento River, it has been observed that many areas of the river exhibit morphologic and hydraulic conditions which may be difficult to hydraulically model using traditional one-dimensional modelling techniques, i.e. PHABSIM. Should these areas prove to be important for certain life stages of the evaluation species, it may be difficult at best to quantify the physical habitat available in these areas. A new generation of models (two-dimensional) is currently being developed by the modelling community which can address physical complexities which PHABSIM cannot. In addition, these models are adept at identifying habitat mosaics and edge effects which are important habitat considerations when evaluations are conducted on multiple species/life stage complexes.

After collaboration with staff from the USGS, Midcontinent Ecological Sciences Center (MESC), some preliminary work was undertaken in FY97 to determine if two dimensional modelling was a viable possibility for this study. MESC is currently developing two-dimensional habitat models in the upper Missouri River Basin on the Missouri and Yellowstone Rivers. In October, 1996 we collected field data to develop a prototype two-dimensional hydraulic model for one of our Merced River study sites. The data were supplied to MESC staff, who were able to construct such a model for the site.

It is our conclusion that this approach would be useful. However, we would require the assistance of MESC to pursue a large-scale two dimensional modelling effort and it appears at this time that they will be unable to provide such assistance in the near future.

REFERENCES

Thomas, J. A. and K. D. Bovee. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers: Research and Management 8:285-294.

APPENDIX A

REDD COUNTS FROM AERIAL REDD SURVEYS

Table A-1
Fall-run Redd Counts from Aerial Redd Surveys

Location/Segment	11/2/94	11/11/93	11/24/92	11/1/91	11/14/90	11/2/89
299 Bridge Riffle Site	123	60	25	91	232	150
Knighton Riffle Site	81	37	19	27	60	70
Turtle Bay Side Channel Site	48	27	12	26	53	32
Posse Grounds Site	37	33	2	63	36	60
Above Hawes Hole Site	18	22	11	43	47	45
Bridge Riffle Site	95	80	8	49	0	43
Tobiasson Riffle Site	24	33	4	29	23	28
Palisades Site	0	32	7	16	34	35
Canyon Creek Site	4	0	0	1	3	0
Total Reach 5	**863**	**536**	**224**	**554**	**867**	**980**
Powerline Riffle Site	37	35	13	41	64	72
Bear Creek Site	67	36	8	9	8	25
Balls Ferry Riffle Site	145	73	69	82	137	127
Price Riffle Site	67	34	7	11	18	63
Cottonwood Riffle Site	22	6	8	7	22	14
Below Cow Creek Site	0	0	0	0	0	0
Total Reach 4	**375**	**213**	**110**	**176**	**273**	**341**
Mud Ball Riffle Site	0	41	27	21	53	57
Laurence Riffle Site	0	42	19	24	27	31
Freitas Riffle Site	57	10	14	5	21	26
Jellys Ferry Riffle Site	74	21	18	11	27	16
Upper Bend Riffle Site	51	26	8	8	36	32
Total Reach 3	**1569**	**676**	**362**	**477**	**942**	**983**
Osborne Riffle Site	56	46	14	67	27	31
Blackberry Riffle Site	52	38	11	23	62	0
Five Fingers Riffle Site	11	12	29	35	63	9
Pipeline Riffle Site	21	11	9	24	26	29
Total Reach 2	**645**	**345**	**199**	**346**	**654**	**354**

Location/Segment	1/28/92	2/13/91	2/15/90	2/11/88	2/10/86	2/5/85
Lower Lake Redding Site	29	11	14	39	0	30
Upper Lake Redding Site	19	6	2	35	24	4
Salt Creek Site	0	12	3	2	0	2
Island Site	2	2	0	4	10	9
Total Reach 6	**62**	**42**	**19**	**80**	**34**	**45**
299 Bridge Riffle Site	12	5	14	25	0	3
Knighton Riffle Site	11	0	5	0	1	0
Turtle Bay Side Channel Site	3	0	11	7	0	2
Posse Grounds Site	4	0	3	9	43	21
Above Hawes Hole Site	2	4	4	13	0	17
Bridge Riffle Site	5	3	6	5	18	3
Tobiasson Riffle Site	2	0	1	6	2	4
Palisades Site	3	0	0	0	0	0
Canyon Creek Site	0	0	0	0	0	0
Total Reach 5	**61**	**39**	**80**	**173**	**81**	**91**
Powerline Riffle Site	0	2	0	1	0	6
Bear Creek Site	0	3	0	0	0	0
Balls Ferry Riffle Site	3	1	1	13	0	0
Price Riffle Site	0	2	0	1	0	2
Cottonwood Riffle Site	0	2	0	1	0	2
Below Cow Creek Site	0	2	0	4	0	0
Total Reach 4	**3**	**12**	**1**	**22**	**0**	**13**

Table A-3
Winter-run Redd Counts from Aerial Redd Surveys

| Location/Segment	1994	1993	1992	1991	1990	1989
299 Bridge Riffle Site	0	1	3	0	0	3
Knighton Riffle Site	0	1	1	0	0	3
Turtle Bay Side Channel Site	0	6	0	0	0	1
Posse Grounds Site	3	7	2	0	11	0
Above Hawes Hole Site	1	0	4	0	0	0
Bridge Riffle Site	2	2	0	3	1	1
Tobiasson Riffle Site	2	2	4	0	2	1
Palisades Site	0	7	5	5	22	12
Canyon Creek Site	0	0	5	0	15	2
Total Reach 5	**14**	**42**	**44**	**10**	**81**	**39**
Powerline Riffle Site	0	0	1	0	0	0
Bear Creek Site	0	0	0	0	‚0	0
Balls Ferry Riffle Site	0	0	0	0	0	0
Price Riffle Site	0	0	2	0	1	0
Cottonwood Riffle Site	1	0	0	0	0	0
Below Cow Creek Site	0	0	0	0	0	0
Total Reach 4	**1**	**0**	**3**	**0**	**1**	**0**

APPENDIX B

PRELIMINARY HABITAT SUITABILITY CRITERIA FOR JUVENILE CHINOOK SALMON REARING IN THE SACRAMENTO RIVER

PRELIMINARY HABITAT SUITABILITY CRITERIA FOR JUVENILE CHINOOK SALMON REARING IN THE SACRAMENTO RIVER

U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3310 El Camino, Suite 130
Sacramento, CA 95821

Prepared by staff of
The Instream Flow Assessments Branch
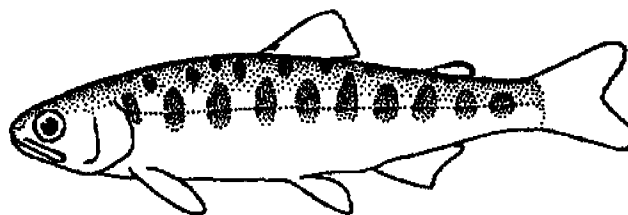
PREFACE

The following is a report prepared as part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (FWS) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this program and the habitat resources of Central Valley rivers are welcomed. Written comments or information can be submitted to:

Jeff Thomas, Chief
Instream Flow Assessments Branch
U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3310 El Camino, Suite 130
Sacramento, CA 95821

STUDY AREA

The study area extended from the Anderson-Cottonwood Irrigation District Diversion Dam (ACID) at river mile (RM) 298.5 to the mouth of Battle Creek (RM 271.4). Battle Creek was chosen as the downstream terminus to preclude the inclusion of juvenile chinook salmon released at the Battle Creek National Fish Hatchery, and the effects these fish might have on naturally produced YOY habitat selection, in the data.

METHODS

Habitat typing conducted by CDFG identified 12 specific mesohabitat types and a total of 142 mesohabitat units in the 27.1 mile section of the Sacramento River between ACID and Battle Creek. This section was divided into three segments, each approximately nine miles long. One unit of each mesohabitat type (excluding side-channel pools) were randomly selected from each segment as study sites. Side-channel pools were excluded because there were only two in the entire study area. In addition, there were no side-channel glides in the entire study area. If a mesohabitat type was not found in one of the segments then one was selected from another segment so that each type was equally represented. The only exception to this was, due to an error in classification of one mesohabitat unit, four side-channel riffles and two side-channel runs were sampled. Table 1 shows the mesohabitat type, number, and location of the study sites selected. There were fewer study sites in the furthest downstream segment (Segment 3). This is a result of the elimination of some of the sites selected in this segment because turbidity, particularly early in the year, rendered these sites impossible to sample effectively, and because some mesohabitat types are not present in Segment 3.

In early January 1996, 47.5 m (150 ft) longitudinal transects were set up at each study site along both river banks by placing fluorescent markers at the up and downstream ends. To reduce bias in transect placement and avoid the influence of mesohabitat boundary effects, all transects were placed 30 m above the bottom boundary of the mesohabitat unit (as determined from aerial photographs). Five sites were divided between different mesohabitat types in the middle of the river. For these sites (#'s 130, 118, 101, 70, 42) only one bank was sampled. Work began on January 10 with the intention of sampling all sites every other week. However, winter storms produced extremely high flows for an extended period from late January through most of March and poor sampling conditions caused by turbid tributary inflow resulted in a more irregular schedule, with a total of eleven sampling trips.

At each study site divers using snorkeling gear would move slowly up the transects counting all fish observed between the waters edge and as far out as visibility allowed (visibility ranged from three to eight feet during the study period and was generally more restricted downstream). Initially, a pair of divers (one adjacent to the edge and the other positioned within view towards mid-channel) would conduct the sampling. After a limited time, however, it was recognized that the outside diver was rarely observing any fish in the swifter waters present there while the inside

Table 1
Chinook salmon YOY sampling habitat units and locations
on the Sacramento River in 1996.

Habitat Type		Segment 1[1]		Segment 2[1]		Segment 3[1]	
		Habitat #	RM	Habitat #	RM	Habitat #	RM
Bar Complex	Run	111	294.5	62	287.2	22[2]	278.3
Bar Complex	Riffle	132	297.3	75	289.0	30	279.9
Bar Complex	Pool	130	297.1	none	-	28	279.6
		118[3]	295.0	-	-	-	-
Bar Complex	Glide	110	294.4	38	281.7	-	-
		-	-	70[4]	288.6	-	-
Flat Water	Run	122	296.1	52	285.8	25	278.6
Flat Water	Riffle	135	297.6	55	286.5	17	277.3
Flat Water	Pool	101	292.4	42	282.2	15	276.8
Flat Water	Glide	99	291.7	51	285.8	27	279.1
Side Channel	Run	93	291.0	none	-	none	-
		82	289.5	-	-	-	-
Side Channel	Riffle	128	297.0	76	289.3	none	-
		92	290.9	-	-	-	-
		83	289.7	-	-	-	-
Off Channel	Area	79	289.4	37	281.4	none	-
				35	281.2	-	-

[1] Segment 1 extends from ACID (RM 298.5) to near Olney Creek (RM 289.5), segment 2 extends from Olney Creek to below Deschutes Road (RM 280.5), segment 3 runs from below Deschutes Road to Battle Creek (RM 271.4).

[2] Habitat Unit 22 replaced unit 2 (5/22/96) because unit 2 was located below Battle Creek.

[3] Unit 118 replaced unit 5 (6/10/96) because unit 5 was located below Battle Creek.

[4] Unit 70 replaced unit 7 (7/31/96) due to visibility and travel distance.

diver was observing many. It appeared obvious that YOY salmon preferred the habitat conditions near the edge of the river. It was also obvious that the outside diver, without the ability to pull himself upstream using the structural elements found near the bank, was going to have trouble traversing the transect when flows were higher. Therefore, the decision was made that only one diver would sample each transect. When possible, this diver would move laterally from the edge towards mid-channel. Fish lengths, determined with the aid of a scale on the PVC wrist cuffs used to record data, were recorded in 10 mm increments. In addition to fish counts, the dominant cover type was described and recorded in each of the eight cells along the transects during each sampling date. A cover coding system was developed to describe the cover elements found in the river (Table 2). All data were transferred to field notebooks immediately upon completion of each dive.

Table 2
Cover Coding System

Cover Category	Cover Code[5]
no cover	0
cobble	1
boulder	2
fine woody vegetation (< 1" diameter)	3
branches	4
log (> 1' diameter)	5
depth (> 3' from surface)	6
overhead cover (< 2' from water surface)	7
undercut bank	8
aquatic vegetation	9
rip-rap	10

[5] In addition to these cover codes, we have been using composite cover codes; for example, 4/7 would be branches plus overhead cover.

Though the river channel away from the banks appeared inhospitable for young salmon, attempts were made to observe fish in this portion of the river. One method employed the use of a grappling anchor attached to a 45.7 m length of rope. The anchor was set 10 to 20 meters out from the bank at the top of each transect. Divers used a hand ascender to pull themselves up the rope, angling their bodies to move laterally. This method (tried during sample weeks 21, 23, and 25) worked well in water up to 6 ft deep with velocities up to 4 ft/s. Faster water could not be sampled efficiently but it was possible to sample deeper pool habitats using SCUBA gear. This method was used during week 23 in Turtle Bay where three divers spent approximately 30 minutes each looking for YOY chinook salmon in water up to 25 ft deep. Only one YOY salmon was observed during any of these attempts.

HSC data were collected for chinook salmon fry and juveniles (YOY) between April 10 and June 27, 1996 using the equal-mesohabitat-type-area sampling methodology recommended by Bovee and Bartholow (1996). Data were collected during two weeks when Keswick releases were approximately 5,000 cfs, one week when releases were around 7,000 cfs, one week when releases were around 14,000 cfs, and one week when releases were around 12,000 cfs. Either the 45.7 m (150 ft) transects used for the snorkel surveys or 45.7 m sections directly above those transects were sampled. Most of the effort was concentrated in areas adjacent to the bank for reasons discussed previously in this report. One person would snorkel along the bank and place a weighted, numbered tag at each location where YOY chinook salmon were observed. The snorkeler would record the tag number, the cover code[6] and the number of individuals observed in each 10 mm size class. Cover availability in the transect cell would also be recorded (same technique as was used in the snorkel survey). Another individual would retrieve the tags, measure the depth and mean water column velocity at the tag location, and record the data for each tag number. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. An adjacent mean water column velocity was also measured within two feet[7] on either side of the tag where the velocity was the highest. This measurement was taken to eventually provide the option of using an alternative habitat model (HABTAV) which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed.

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[6] If there was no cover elements (as defined in Table 2) within one foot horizontally of the fish location, the cover code was 0 (no cover).

[7] Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Sacramento River is around four feet (ie., four feet x ½ = two feet).

Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth.

Data taken by the snorkeler and the measurer were correlated at each tag location and entered into a spreadsheet for eventual analysis and development of HSC. All YOY chinook salmon observed have been classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. Data were also compiled on the length of each mesohabitat and cover type sampled to ensure that equal effort would eventually be spent in each type and that each location was only sampled once at the same flow (to avoid problems with pseudoreplication). These efforts will continue over the next two years with increased effort to sample in mid-channel areas where YOY salmon have been observed in previous years by other investigators (Keith Marine, personal communication).

Preliminary HSI criteria were derived by combining together all of the data collected, because there has been insufficient data collected thus far to develop HSI for different size classifications of YOY salmon. Using the HSC data collected and entered into a spreadsheet, frequency distributions were calculated for depth and velocity. Depth and velocity criteria were then developed from the data directly in the spreadsheet using the nonparametric tolerance limits method described by Bovee (1986). Specifically, depths and velocities within the middle 50% of the distribution of HSC measurements were assigned suitabilities of 1.0. In addition, HSI values of 0.5, 0.2, and 0.1 were assigned to the depths and velocities at, respectively, 75%, 90%, and 95% of the distribution of HSC measurements, while depths and velocities which were outside of the range of HSC measurements were assigned a suitability of 0.0. The only exception to this procedure was for the HSI value for a 0.00 ft/s velocity. Since 15.7% of the HSC measurements had a velocity of 0.00 ft/s, the correct HSC value for 0.00 ft/s is between 0.5 and 1.0[8]. The HSI value assigned to a velocity of 0.00 ft/s was 0.63 (four times 15.7%)[8].

The model HABTAV uses three parameters to evaluate the suitability of adjacent velocities: DIST, the distance to the adjacent cell; VO, the minimum adjacent velocity where fish habitat is greater than 0; and VLIM, the minimum adjacent velocity where the multiplier used by HABTAV to adjust WUA is one. The above is based on using the following IOC options in HABTAV: IOC(1) = 1 and IOC(5) = 1. As discussed above, we defined DIST = 2 feet, based on the delivery of food from an adjacent cell to the fish's location by turbulent mixing. Since we observed fish with an adjacent velocity of 0.00 ft/s, the appropriate value for VO is 0.00 ft/s. The adjacent velocity data collected was sorted in ascending order and the cumulative percentile values were calculated for each observation, with the observation with the lowest adjacent

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[8] If 12.5% of the HSC measurements had a velocity of 0.00 ft/s, the HSI value for 0.00 ft/s would be 0.5, while if 25% of the HSC measurements had a velocity of 0.00 ft/s, the HSC value for 0.00 ft/s would be 1.0. Note that in both cases, the HSC value is 4 times the percentage of HSC measurements.

velocity having a cumulative percentage of 0% and the observation with the highest adjacent velocity having a cumulative percentage of 100%. A linear regression, with the intercept fixed at 0, was then performed on the cumulative percentage versus adjacent velocity. The predicted adjacent velocity at a cumulative percentage of 100% was then calculated from the resulting linear regression equation. The value of VLIM is this predicted adjacent velocity (1.61 ft/s).

We were unable to develop cover criteria from the HSC measurements because of unequal sampling of different cover types. As a result, we developed preliminary cover HSI from the snorkel survey data using the methods of Rubin et al (1991). Specifically, for each cover type we calculated the average number of fish per cell[9]. The preliminary HSI value for each cover type was then calculated by dividing the average number of fish for that cover type by the average number of fish in the cover type with the highest average number of fish. Insufficient cells with depth cover (cover code 6) were sampled to be able to develop an HSI value for this cover type.

RESULTS

Two hundred eighty-two measurements (depth and velocity) were taken where YOY chinook salmon were observed. All of these measurements were made near the river banks. There were 140 observations of fish less than 40 mm, 219 observations of 40-50 mm fish, 99 observations of 50-60 mm fish, 48 observations of 60-80 mm fish and 9 observations of fish greater than 80 mm[10]. According to the race classification table, these numbers account for 210 fall-run and 167 late fall-run YOY chinook salmon. A total of 5.8 miles of near-bank habitat and 1.6 miles of mid-channel habitat was sampled. Tables 3 summarizes the number of meters of different mesohabitat sampled and Table 4 summarizes the number of meters of different cover types sampled. Table 5 presents the preliminary HSC criteria.

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[9] As noted above, there were eight cells per 150 ft longitudinal snorkel survey transect. All cells were used to calculate the average number of fish per cell, even those with no fish observed.

[10] These numbers total much more than 282 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

Table 3
Distances (meters) Sampled for Juvenile Chinook Salmon HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
Bar Complex Glide	732	914
Bar Complex Pool	503	274
Bar Complex Riffle	1006	274
Bar Complex Run	823	183
Flatwater Glide	960	137
Flatwater Pool	640	0
Flatwater Riffle	1009	366
Flatwater Run	869	274
Off-Channel Area	274	0
Side-Channel Riffle	1829	82
Side-Channel Run	732	0

Table 4
Distances (meters) Sampled for Juvenile Chinook Salmon HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled
None	2262	156
Cobble	2701	1324
Boulder	643	80
Fine Woody	944	0
Branches	1629	61
Log	314	0
Depth	0	884
Overhead	182	0
Undercut	267	0
Aquatic Vegetation	389	0
Rip Rap	46	0
Overhead + instream	1810	0

Table 5
Chinook salmon YOY Preliminary HSI Criteria

Depth	HSI	Velocity(ft/s)	HSI	Cover Code	HSI
0.0	0.0	0.00	0.63	0	0.20
0.1	0.0	0.11	1.00	1	0.09
0.2	0.1	0.50	1.00	2	0.13
0.3	0.2	0.73	0.50	3	0.13
0.5	0.5	0.89	0.20	3.7	0.63
0.7	1.0	1.24	0.10	4	0.48
1.7	1.0	1.75	0.00	4.7	0.87
2.3	0.5			5	0.27
3.0	0.2			5.7	1.00
4.0	0.1			7	0.90
5.6	0.0			8	0.24
				9	0.09
				9.7	0.58
				10	0.01

| DIST(ft)	VO(ft/s)	VLIM(ft/s)
2.0	0.00	1.61

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Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper 21. U. S. Fish and Wildlife Service Biological Report 86(7). 235 pp.

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APPENDIX C

SUPPLEMENTAL REPORT ON THE INSTREAM FLOW REQUIREMENTS FOR FALL-RUN CHINOOK SALMON SPAWNING IN THE LOWER AMERICAN RIVER

SUPPLEMENTAL REPORT ON THE INSTREAM FLOW REQUIREMENTS FOR FALL-RUN CHINOOK SALMON SPAWNING IN THE LOWER AMERICAN RIVER
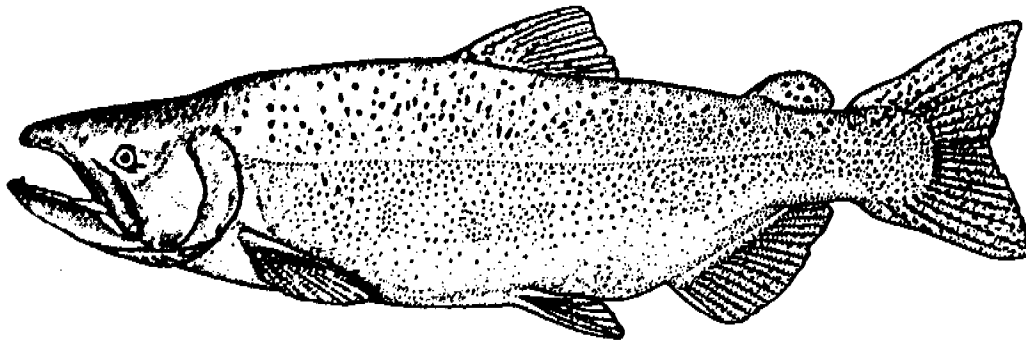
U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3130 El Camino, Suite 130
Sacramento, CA 95821

Prepared by staff of
The Instream Flow Assessments Branch

February 1997

PREFACE

The following is a supplemental report for the U.S. Fish and Wildlife Service's investigations on the Lower American River, part of the Anadromous Doubling Plan Instream Flow Investigations, a 5-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service after consultation with the California Department of Fish and Game (CDFG). The purpose of these investigations is to provide scientific information to the U.S. Fish and Wildlife Service Central Valley Anadromous Fish Restoration Program to be used to develop such recommendations for Central Valley rivers.

To those who are interested, comments and information regarding this report are welcomed. Written comments or information can be submitted to:

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Jeff Thomas, Chief
Instream Flow Assessment Branch
U.S. Fish and Wildlife Service
Ecological Services
Sacramento Field Office
3130 El Camino, Suite 130
Sacramento, CA 95821

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The field work for this supplemental report was conducted by Jeff Thomas, Mark Gard and Sean Gallagher. Data analysis and report preparation were performed by Mark Gard and Jeff Thomas.

ANADROMOUS DOUBLING PLAN INSTREAM FLOW INVESTIGATIONS LOWER AMERICAN RIVER FALL-RUN CHINOOK SPAWNING SUPPLEMENTAL REPORT

INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter and spring runs), steelhead, and white and green sturgeon. For the Lower American River, the Central Valley Project Improvement Act Anadromous Doubling Plan calls for October through February (during fall-run chinook salmon spawning) flows at the H Street Bridge ranging from 1,750 cfs in critically dry years to 2,500 cfs in wet years. In December 1994, the U.S. Fish and Wildlife Service prepared a study proposal to identify the instream flow requirements for anadromous fish in certain streams within the Central Valley of California, including the Lower American River. In March 1996, the U.S. Fish and Wildlife Service released a final report on physical habitat availability for spawning steelhead trout and fall-run chinook salmon (*Identification of the Instream Flow Requirements for Steelhead and Fall-Run Chinook Salmon Spawning in the Lower American River*). Five different sets of habitat suitability criteria (HSC or HSI Curves) were used to predict weighted useable area (WUA) over a range of streamflows for chinook salmon spawning. One of these sets was site-specific for the Lower American River, however, the criteria were developed from CDFG data not specifically intended for this purpose. The data base was not as large (N=118) as would have been preferred and over 20% of the data were collected in 1992 (a drought year when river flows were around 1000 cfs during the fall). The 1996 spawning season presented an opportunity to develop new site-specific HSC which better represent the physical habitat conditions selected by spawning fall-run chinook salmon in the Lower American River. This supplemental report details the procedures followed in the development of these criteria and presents habitat modeling results obtained using these HSC.

METHODS

Field Data Collection

The primary habitat variables which are used to assess physical habitat suitability for spawning chinook salmon are water depth, velocity, and substrate composition (including embeddedness). Data relative to these variables were collected from 218 fall-run chinook salmon redds on November 6 and 7, 1996 in five of the study sites previously used for habitat modeling (Above Sunrise 14, Above Sunrise 16, At Sunrise 26, Below Sunrise 29 and Below Sunrise 30). Measurements were taken with a wading rod and a Price-AA velocity meter equipped with a current meter digitizer. All recently constructed redds (redds without periphyton) within each study site which could be conclusively identified were measured. Depth and velocity data were collected two to four feet upstream of the pot which was assumed to have hydraulic conditions

similar to the redd location prior to redd construction. Depth was recorded to the nearest 0.1 ft and mean water column velocity was recorded to the nearest 0.1 ft/s. Substrate (Table 1) was visually assessed in the tailspill for the dominant particle size range (e.g., range of 1-2"). Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. Releases from Nimbus Dam averaged 2780 cfs during the sampling period. All data were entered into a spreadsheet for analysis and development of HSC (HSI Curves).

Table 1
Substrate Descriptors and Codes

Code	Type	Particle Size (inches)
0	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium Gravel	1 - 3
1.4	Medium Gravel	1 - 4
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Cobble	3 - 4
3.5	Cobble	3 - 5
3.6	Cobble	3 - 6
4.5	Cobble	4 - 5
4.6	Cobble	4 - 6
5.6	Cobble	5 - 6
6.8	Cobble	6 - 8
8	Cobble	8 - 12
9	Boulder	12 - 24
10	Boulder	> 24
11	Bedrock	

Using the data collected from the 218 redds and entered into a spreadsheet, frequency distributions were calculated for depth and velocity and input into the PHABSIM suitability index curve development program (CURVE). The HSI curves were then computed using exponential smoothing. The curves generated were exported into a spreadsheet and modified by truncating at the lower end, so that the next depth or velocity value below the lowest observed value had a SI value of zero; and eliminating points not needed to capture the basic shape of the curves.

Substrate criteria were developed by: 1) determining the number of redds with each substrate code (Table 1); 2) calculating the proportion of redds with each substrate code (number of redds with each substrate code divided by total number of redds); and 3) calculating the HSI value for each substrate code by dividing the proportion of redds in that substrate code by the proportion of redds with the most frequent substrate code.

The initial HSC showed suitability rapidly decreasing for depths greater than 2 feet. This effect was likely due to the low availability of deeper water in the Lower American River with suitable velocities and substrates rather than a selection by the salmon of only shallow depths for spawning[1]. The following method was used to correct the depth criteria for the low availability of deeper water with suitable velocities and substrates. Based on the distribution of velocity and substrate redd data, we concluded that suitable velocities were between 1.3 and 3 ft/s, while suitable substrates were 1-3 to 3-4 inches in diameter (i.e., substrate codes 1.3, 1.4, 2.3, 2.4 and 3.4). A series of HSC sets were constructed where: 1) each set held velocity and substrate HSI values at 1.0 for the velocity and substrate range noted above with all other velocities and substrates assigned a value of 0.0; and 2) each set assigned a different 0.5-foot depth increment an HSI value of 1.0 for depths between 2.0 and 6.0 feet deep, with the other 0.5 foot increments and depths less than 2.0 foot and greater than 6.0 feet given a value of 0.0 (e.g., 2.0-2.5' depth HSI value equal 1.0, <2.0' and >2.5' depths HSI value equals 0.0 for set #1, etc.). Thus, eight sets of HSC were constructed differing only in the suitabilities assigned for optimum depth ranges. Each HSC set was run through the *HABTAE* program using the output of the calibrated hydraulic decks for the five study sites at which HSC data was collected, with the resulting habitat output combined in a spreadsheet to determine the available river area with suitable velocities and substrates for the 0.5-foot depth increments from 2 to 6 feet. The redd data were used to determine the number of redds in each of the above depth increments to assess use. Relative availability and use were then computed by dividing the availability and use for each depth increment by the largest availability or use, thus scaling both measures to have a maximum

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[1] Areas of the river with depths up to six feet were sampled with approximate equal effort as those with depths less than three feet and few redds were found. This sampling confirmed that substrate size and water velocities were generally unsuitable in deeper water.

value of 1.0. Linear regressions of relative availability and use versus the midpoint of the depth increments (i.e., 2.25' for 2-2.5' depth increment) were used to remove noise from the data and produce linearized values of relative availability and use at the midpoints of the depth increments. The results of the regressions showed that availability dropped with increasing depth, but not quite as quickly as use. For the range of depths where the regression equations predicted positive relative use and availability, linearized use was divided by linearized availability, and the resulting ratios were scaled so that the maximum ratio was 1.0. A third linear regression of the scaled ratios versus the midpoint of the depth increments was used to determine the depth at which the scaled ratios reached zero. The result of this regression was that the scaled ratio reached zero at 10.8 feet; thus, the depth criteria were modified to have a linear decrease in suitability from 1.0 for the highest depth in the original criteria which had a suitability of 1.0, to a suitability of 0.0 at 10.8 feet. The resulting criteria are show in Figures 1 through 3 and Appendix A.

These HSC differ substantially from the previous Lower American River criteria presented in the March 1996 report. As mentioned above, those HSC were developed from data not collected for this purpose and appear biased toward shallow depths and slower velocities. As a result, we recommend that those criteria not be used.
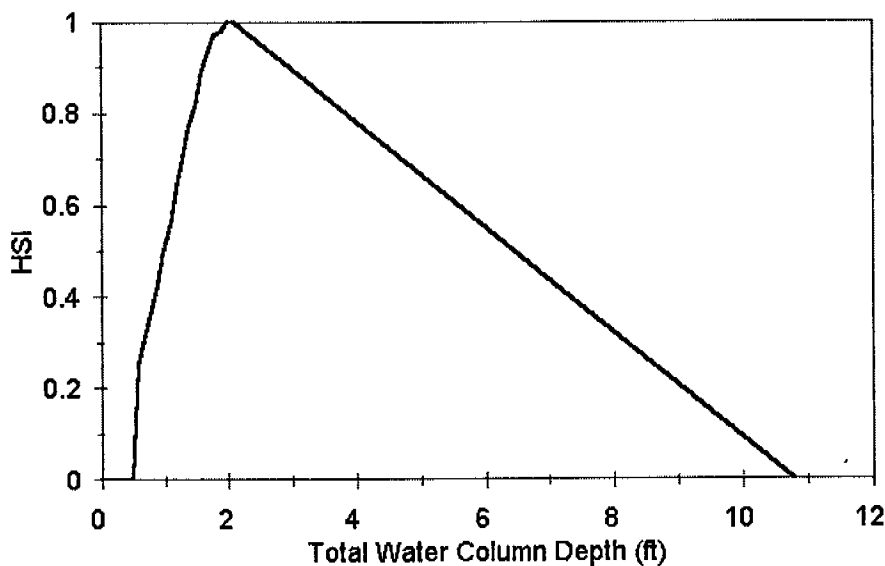
Figure 1
Fall-run Chinook Salmon HSI Curve for Depth
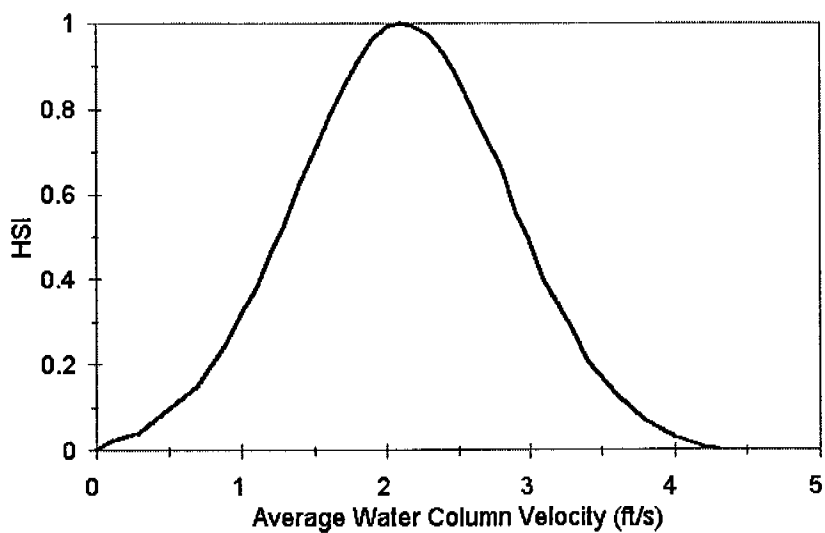
Figure 2
Fall-run Chinook Salmon HSI Curve for Velocity
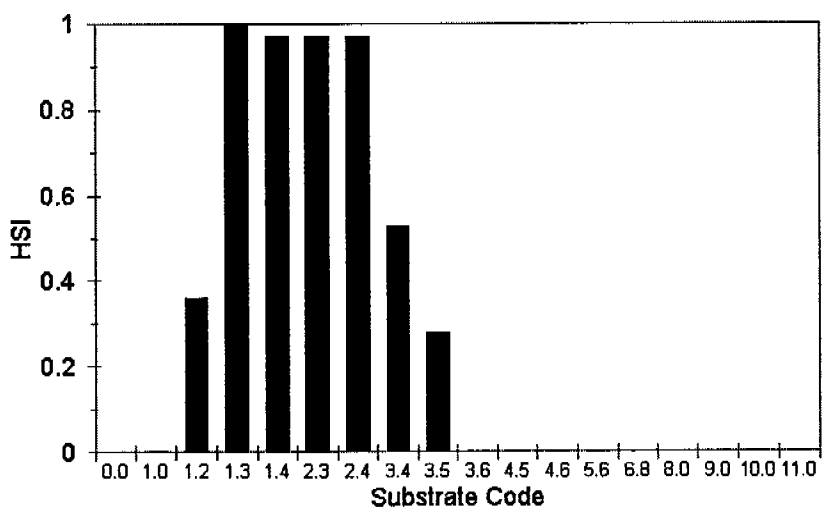
Figure 3
Fall-run Chinook Salmon HSI Curve for Substrate

Habitat Simulation

After creating an input file with the HSC set in Appendix A, habitat simulations were run using the *HABTAE* program to predict physical spawning habitat availability for chinook salmon in the Lower American River at flows between 1000 and 6000 cfs by 200 cfs increments.

RESULTS

Weighted Usable Area (WUA) was computed using the criteria set cited above and is presented in Appendix B. These results are presented by transect at the request of CDFG, the primary recipient of this report. The information contained herein will presumably be considered, along with empirical data which continues to be collected, in formulating instream flow recommendations that should benefit the fall chinook salmon population of the Lower American River.

APPENDIX A

HSI CRITERIA

Water Velocity (ft/s)	SI Value	Water Depth (ft)	SI Value	Substrate Composition	SI Value
0.00	0.00	0.00	0.00	0.0	0.00
0.10	0.02	0.50	0.00	1.0	0.00
0.30	0.04	0.60	0.25	1.2	0.36
0.40	0.07	0.70	0.31	1.3	1.00
0.70	0.15	0.90	0.43	1.4	0.97
0.90	0.25	1.00	0.50	2.4	0.97
1.00	0.32	1.10	0.56	3.4	0.53
1.10	0.38	1.20	0.64	3.5	0.28
1.20	0.46	1.30	0.70	3.6	0.00
1.30	0.53	1.40	0.77	100.0	0.00
1.40	0.62	1.50	0.82		
1.50	0.70	1.60	0.89		
1.60	0.78	1.80	0.97		
1.70	0.85	1.90	0.98		
1.80	0.91	2.00	1.00		
1.90	0.96	2.10	1.00		
2.00	0.99	10.80	0.00		
2.10	1.00	100.00	0.00		
2.20	0.99				
2.30	0.97				
2.40	0.93				
2.50	0.88				
2.60	0.80				
2.70	0.73				
2.80	0.67				
2.90	0.56				
3.00	0.49				
3.10	0.40				
3.30	0.28				
3.40	0.21				
3.60	0.13				
3.80	0.07				
4.00	0.03				
4.20	0.01				
4.30	0.00				
100.00	0.00				

APPENDIX B

HABITAT MODELING RESULTS

| | Sailor Bar | | | Above Sunrise 14 | | Above Sunrise 16 | |
Flow	XS 1 LC	XS 1 RC	XS 2	XS 1	XS 2	XS 1	XS 2
1000	45.7	2.4	107.3	133.1	85.4	12.7	12.9
1200	42.9	3.2	140.1	158.5	107.8	21.8	24.6
1400	37.1	4.2	168.5	175.4	126.9	30.4	36.2
1600	30.2	5.3	190.8	184.1	141.7	37.4	48.6
1800	24.6	6.2	205.9	187.0	151.9	44.0	59.1
2000	20.3	7.2	213.1	185.2	158.2	47.9	65.6
2200	16.7	8.4	212.9	180.9	160.6	49.9	69.7
2400	13.4	9.5	206.5	174.8	160.5	51.5	70.6
2600	11.5	10.6	195.0	168.9	158.0	51.1	69.9
2800	10.3	11.7	179.1	163.5	154.1	49.8	67.2
3000	9.2	13.0	162.4	157.6	149.4	48.2	63.6
3200	8.0	14.1	144.3	152.6	144.2	46.1	59.4
3400	7.3	15.1	126.2	147.6	138.4	44.0	54.9
3600	6.5	16.1	109.1	142.0	132.4	41.2	50.1
3800	6.0	16.9	94.0	137.1	126.2	38.6	45.5
4000	6.0	17.8	78.8	131.3	119.4	38.5	45.3
4200	5.8	18.6	65.8	125.6	112.6	36.3	41.4
4400	5.8	19.4	54.1	119.9	105.1	33.6	37.7
4600	5.8	20.2	44.0	113.2	98.1	31.4	34.1
4800	5.9	20.9	35.9	106.8	91.1	29.1	30.8
5000	6.1	21.5	28.9	100.0	84.1	27.3	28.2
5200	6.8	22.0	22.9	93.1	77.2	25.5	25.6
5400	7.3	22.5	18.2	86.0	70.6	23.7	23.4
5600	7.8	23.0	14.4	79.1	63.9	22.1	21.3
5800	8.3	23.4	11.3	72.3	57.4	20.8	19.4
6000	8.8	23.8	8.7	65.2	51.8	19.5	17.8

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).

| | Above Sunrise 23 | | At Sunrise 26 | | Below Sunrise 29 | |
Flow	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2
1000	77.3	65.7	90.8	163.7	115.3	86.1
1200	82.8	66.2	105.6	185.7	136.6	97.1
1400	86.3	69.6	114.0	196.6	151.3	102.9
1600	91.2	68.4	116.4	198.2	159.0	103.6
1800	94.4	65.9	113.5	192.0	159.3	100.8
2000	96.8	70.9	107.8	181.3	154.6	95.4
2200	98.4	70.7	99.2	168.1	146.2	88.3
2400	98.5	69.8	89.5	154.1	134.6	80.1
2600	98.2	68.3	79.1	140.1	121.9	71.9
2800	96.9	65.7	69.6	126.8	108.5	63.4
3000	94.2	62.8	60.8	115.8	95.5	55.5
3200	91.4	60.3	53.0	106.0	82.9	48.4
3400	87.9	57.2	46.4	97.0	71.7	42.3
3600	83.9	54.3	40.7	88.9	61.3	36.8
3800	79.6	51.7	35.8	81.3	52.8	31.9
4000	74.4	48.9	31.5	75.0	45.4	27.8
4200	69.6	46.0	28.1	69.0	39.2	24.2
4400	64.9	43.4	25.5	63.4	34.0	21.1
4600	60.2	40.7	23.5	58.0	29.7	18.5
4800	55.9	38.5	21.9	53.1	26.3	16.3
5000	51.7	36.4	20.5	48.5	23.5	14.5
5200	48.0	34.5	19.3	44.2	21.4	13.1
5400	44.5	32.4	18.4	40.2	19.9	12.0
5600	41.2	30.4	17.8	36.5	18.7	11.0
5800	38.2	28.6	17.3	32.7	17.7	10.2
6000	35.5	26.7	16.9	29.5	17.0	9.7

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).

	Below Sunrise 30		El Manto		Rossmoor 2		Rossmoor 1	
Flow	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2	XS 1	XS 2
1000	51.0	61.0	25.2	34.3	34.6	62.6	33.0	3.8
1200	58.3	72.0	26.4	34.2	34.4	65.8	30.7	4.1
1400	65.0	84.0	26.6	32.8	32.6	67.3	27.0	4.2
1600	69.8	94.6	26.2	30.8	31.9	66.6	23.2	4.3
1800	72.8	101.9	25.8	29.5	31.0	65.5	20.0	4.4
2000	73.0	105.3	25.0	28.4	31.0	63.1	17.4	4.4
2200	71.3	105.1	24.2	27.9	30.5	59.4	14.9	4.4
2400	68.2	100.3	23.2	27.6	30.5	57.4	13.2	4.4
2600	64.0	93.7	22.5	27.7	30.9	54.5	11.6	4.4
2800	58.9	85.1	21.8	27.7	31.9	52.0	10.3	4.4
3000	53.6	76.0	20.9	27.7	33.3	50.4	9.3	4.3
3200	48.3	68.2	20.2	27.7	34.3	47.9	8.4	4.2
3400	43.2	60.7	19.5	27.7	34.1	46.4	7.6	4.1
3600	38.9	54.2	19.0	27.5	34.1	44.5	6.9	4.1
3800	35.0	48.2	18.3	27.3	33.4	42.9	6.4	4.1
4000	31.6	43.4	17.8	26.7	32.1	41.1	6.0	4.0
4200	28.8	39.7	17.2	26.3	30.6	39.2	5.6	4.0
4400	26.5	36.7	16.6	25.6	28.8	37.3	5.1	3.9
4600	24.4	34.2	15.9	24.6	27.2	35.2	4.8	3.9
4800	22.6	31.9	15.1	23.8	25.3	33.6	4.5	3.9
5000	21.0	30.0	14.5	23.1	23.2	31.6	4.1	3.9
5200	20.0	28.5	13.9	22.3	21.4	29.9	3.8	3.8
5400	19.3	26.9	13.2	21.3	19.8	28.5	3.6	3.8
5600	18.5	25.7	12.6	20.5	18.3	27.2	3.5	3.7
5800	17.8	24.6	12.1	19.9	16.8	26.0	3.3	3.6
6000	17.6	23.6	11.7	19.6	15.2	25.0	3.1	3.5

Data in above table is Weighted Useable Area (1000 square feet per 1000 feet of stream) for the criteria set in Appendix A. Flow is release from Nimbus Dam (cfs).